Precise Lifetime Measurement for the $1s^22p\ ^2P_{3/2}$ Level of Li-like Ni

Y. Zou[1,5], D. Feili[2], R. Hutton[3], C. Neacsu[2], K.-H. Schartner[2], X. Ma[4,5] and P.H. Mokler[5]

[1] Applied Ion Beam Lab., Fudan University, Shanghai, China,
[2] I. Physik. Inst., University of Giessen, Giessen, Germany,
[3] Dept. of Physics, Lunds University, Lund, Sweden,
[4] Institute of Modern Physics, Lanzhou, China,
[5] GSI, Darmstadt, Germany.

Beyond measurements of accurate transition energies giving access to the atomic structure, a precise determination of lifetimes of excited states yields detailed information on the electronic wave functions involved. For heavy few-electron ions relativistic and quantum-electrodynamic effects determine these atomic quantities. Using the GSI 5m grazing incidence spectrometer intra L-shell VUV-transitions mainly in Li-like heavy ions in the mid-Z range ($28 \le Z \le 54$) have been measured on a $5 \cdot 10^{-5}$ level of accuracy [1]. (For results of Be-like ions see Feili *et al.* in this report.) In this high field domain of atomic species, both higher order QED terms and relativistic effects could sensitively be tested. For this Z region deviations in the oscillator strengths are also expected due to the relativistic character of the wave functions. This is especially true for the $1s^22p\ ^2P_{3/2}$ level in Li-like ions, and the lifetime of this level can precisely be determined in this Z region with the available VUV spectrometer using the beam foil technique.
Moreover, in two recent papers, systematic problems with beam foil lifetime measurements were reported [2], [3]. One of these problems, blending of the line of interest by satellite lines [2], leads to a systematic shortening of the measured lifetimes. The other problem, caused by foil aging [3], also leads to systematic changes in measured decay rates. Remedies for both of these problems were mentioned in these papers. In the work described here the previous results are extended to a higher member of the Li I iso-electronic sequence, to Li-like Ni where high-resolution spectroscopy measurements have already been performed at GSI (the $2p\ ^2P_{3/2} - 2s\ ^2P_{1/2}$ transition wave length is in the region of 16.5 nm) [4].

A high-intensity and very stable beam of 5.9 Mev/u Ni^{9+} ions penetrated a typically 90 μg/cm^2 thick C exciter foil in the spectrometer. The foil distance to the viewing slit of the spectrometer was remotely varied; and the beam was normalized to the integrated current in a down-stream Faraday cup. The ion energy was chosen on the low side of that required to produce most abundantly Li-like charge states, i.e. it was optimized to produce also a high fraction of satellite lines. The spectrometer was calibrated using an on-line penning light source and checking in-beam Be-like reference lines. After intensive pre-bombardement of the foil in order to avoid aging effects, a high statistic decay curve was obtained for the decay of the $1s^22p\ ^2P_{3/2}$ state over a period of 36 hours. Between each foil position a separate recording at a fixed foil position was obtained in order to correct for beam fluctuations. The measuring procedure is described in [3]. The experimental points and the fitted final decay curve are shown in Fig 1. The only known deviation in the lifetime extracted from the measured decay curve should come from the satellite problem.

At the beam energy used here, there was a possible line-blending problem for a Be-like $2s2p\ ^3P - 2p^2\ ^3P$ transition. The influence of this line on the decay curve was taken into account

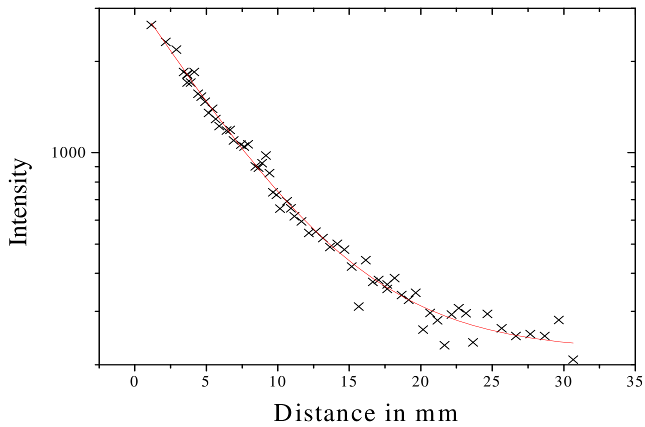

Figure 1. The decay of the $1s^22p\ ^2P_{3/2}$ level for Li-like Ni.

using other branches from the same multiplet and measuring the decay of the upper level in another channel and doing a blend reduction using the ANDC computer code [5]. The final result assuming a constant background is shown in Fig. 1 by the full curve. The present data evaluation yields a final decay time of 0.168 ±0.006 ns which is in full agreement with theory (0.174 ns) [6] within the error bar. An influence of satellite lines cannot be stated for this case: Already in [2] it was suggested that satellite problems may only appear for a small range of Z values within each iso-electronic sequence due to the different scalings with Z for the decays involved.

The present measurement is the first precise lifetime measurement utilizing the GSI 5m grazing incidence spectrometer. It demonstrates its unique capability to determine accurately lifetimes for excited states with transitions in the extreme VUV range, here with an accuracy of 4%. The case study chosen is sensitive on the relativistic influence to the wave functions. Actually it is at the minimum of the scaled oscillator strengths for this transition where relativistic effects start to dominate. Here, the result is in full agreement with the relativistic calculation and fits to the sequence of neighboring measured values. A satellite contribution was not observed for the case studied.

Acknowledgement: The help of Ruediger Schill and Sven Kammer during the beam time is highly appreciated. Work partially supported by EU grant EC-HPRI-CT-1999-00001.

References

[1] Feili D. *et al.,* Phys. Rev. A62, 022501 (2000).
[2] Zou Y, Hutton R. *et al.,* Phys. Rev. A60, 982 (1999).
[3] Zou Y., Hutton R. *et al.,* Phys. Script. T92, 253 (2001).
[4] Staude U. *et al.*, Phys. Rev. A58, 3516 (1998).
[5] Curtis L. *et al.*, Phys. Lett. 34A, 169 (1971).
[6] C. E. Theodosiou, *et al.*, Phys. Rev. A44, 7144 (1991).